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GIS-BASED MAPPING AND MORPHOMETRIC ANALYSIS OF FLOOD PRONE SITES IN THE THREE WATERSHEDS OF BUKIDNON

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ABSTRACT

This study applied the combined technologies of geographic information system (GIS) and global positioning system (GPS) with digital elevation model (DEM) in mapping flooded sites and the morphometric attributes in the Manupali, Taganibong and Maramag watersheds of Bukidnon. The geospatial analysis focused on morphometric characteristics of the watershed as the influencing parameters of flooding which was done mainly within GIS environment using DEM, GPS and survey data on flood extent and depth. DEM database was generated from the topographic map of NAMRIA with 1:50,000 scale and 20-m contour interval. DEM obtained from PhilGIS was also used in the study. Boundary and stream network of the three watersheds were also delineated using MapWindow Open Source GIS. Morphometric parameters of the watershed such as basin shape, area, elongation ratio, circularity ratio, form factor value, relief ratio, elevation, slope, stream order, stream frequency, stream density, among others were also determined. Geospatial analysis of these parameters was made in relation to flooding within the three watersheds. Results showed that flood coverage can be delineated based on the topographic attributes of the watersheds and survey data on flood depth within specific locations. Highly flooded areas are concentrated in the low lying portions of the watersheds. The likelihood of wider flood coverage was directly affected by the size of

floodplains and the configuration of the landscape as characterized by contour line crenulations. Although the output was highly dependent on data input, this research endeavor demonstrated the capability and usefulness of GIS and GPS as important state-of-the-art technologies in flood risk monitoring and management. Geospatial visualization of flood-prone areas and generation of databases on watershed morphometry may aid local governing units to have a scientific basis for a more efficient implementation of disaster risk reduction and mitigation initiatives. The generated information can also be used in developing strategies of local governments and aid agencies on flooding disaster preparedness and risk management, natural resources management, and land use zoning.

Keywords: geographic information system, global positioning system, digital elevation model, geomorphology, disaster risk reduction and management

INTRODUCTION

Flooding has amplified in recent decades due to increasing rainfall intensities and changes in the environment. Human activities such as unplanned rapid settlement development, uncontrolled cultivation and infrastructure construction can influence the spatial and temporal natural hazards [1]. Damage due to flood had been reported in Bukindon particularly Bangcud and Maramag areas [2]. However, data on the behavior and the likelihood of flooding in relations to the geomorphologic features of the watershed remains wanting. Thus, this study focused on assessing the extent of flooding as a function of different geomorphologic characteristics within the Manupali, Taganibong and Maramagwatersheds in Bukidnon. Applying GIS and DEM, the flood prone areas within the three watersheds weregeomorphologically analyzed. Outcome of this study is expected to aid in designing a vulnerability assessment tool as basis for flood risk monitoring and management at the local level. Basically, the study aimed to analyze and visualize the extent of flooding using GIS, GPS and DEM as well as to determine the respective geomorphologic characteristicsof Manupali, Taganibong and Maramagwatersheds.

METHODOLOGY

The study was conducted in Manupali, Taganibong and Maramag watersheds of Bukidnon (Figure 1). The three watersheds lie between 124^0 50’ and 125^0 10’ East and $7^0$40’ and 8^0 10’ North. The households were the

sampling units, which constituted the population of the study and treated as georeferenced point. The unavailability of randomly selected respondents, census was done using the combined snowball and purposive sampling techniques instead [16]. Collection of coordinates containing flood depth and flood extents using GPS receiver was simultaneously done during census. Basically, the study used DEMs available from PhilGIS website to delineate the boundary, river network and other geomorphic features of the three watersheds within MapWindow GIS [17 and 18]. Geospatial analyses were made to determine and visualize the spatial distribution of flooding.

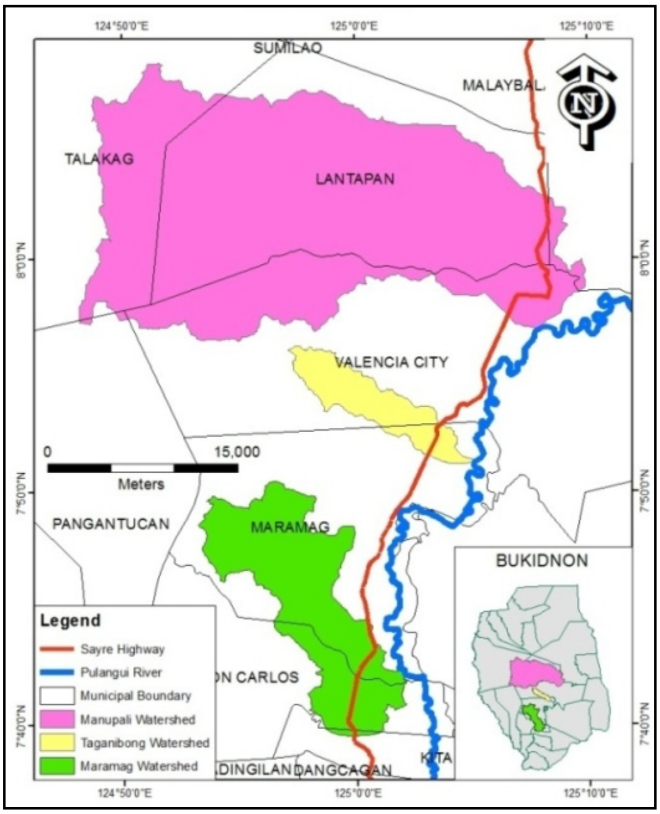


Figure 1: Location map

RESULTS AND DISCUSSION

Table 1 summarizes the different geomorphologic characteristics of the three watersheds. These are grouped into three main parameters namely; basin shape, relief features and stream morphology. The threshold for watershed delineation is the minimum limit of the MapWindow Open Source

GIS to delineate the boundary and stream network.

Basin Shape Parameters

The basin shape parameters included area, perimeter, basin length and width, form factor, elongation and circularity. These are important parameters because these directly and indirectly affect the hydrologic processes, particularly duration and magnitudes of peak flow, mean runoff and lag time in the hydrograph [7, 9, 19, 20, 21, 22 and 23]. Based on the morphologic parameters, Manupali is expected to receive more precipitation due to its larger size than the other two watersheds implying greater volume of water discharged at the outlet point, considering all other factors equal. Conversely, rainwater will reach the main channel at a longer period due to its inherent larger size and longer total channel length [20]. On the other hand,Taganibong is the most elongated while Maramag is least as described by their form factor values. Form factor values nearer to zero indicate high elongated shapes and the values that are closer to unity indicate circular shapes [20]. These values directly conform to the elongation ratio for the three watersheds. Elongated watershed has lower runoff rates because it is unlikely to be uniformly covered by intense rainfall events [6 and 7]. On the other, Taganibong sub watershed suggests an immediate peak runoff during shorter storm events due to its long, narrow and smaller size.

Table 1: Geomorphologic characteristics of the three watersheds

Parameters	Watersheds		
	Manupali	Taganibong	Maramag
Basin Shape Parameters			
Area (Ha)	56,926.8	4,358.2	9,530.4
Basin length (Km)	42.9	17.3	17.0
Basin width (Km)	16.5	3.4	6.7
Form factor	0.31	0.15	0.33
Elongation ratio	0.63	0.43	0.65
Circularity ratio	0.37	0.30	0.41
Relief Features			
Mean elevation (m)	1,162.0	684.0	466.0
Total basin relief (m)	2,534.0	1,042.0	995.0
Relief ratio	0.06	0.06	0.06
Relative relief	0.02	0.02	0.02
Mean slope (%)	23.0	13.0	12.6
Stream Parameters			
Number of stream	539	148	240
Stream frequency (stream/ha)	0.009	0.03	0.02
Drainage density (m/ha)	12.8	19.7	16.8

Relatively, Taganibong watershed has lower chances of flooding due to its elongated shape, thus longer channel slope affecting lag time. On the other hand, the tendency of Manupali watershed has the tendency to have higher runoff rates than watersheds of the same size because compact shape watershed is more likely to be uniformly covered by intense rainfall events [6]. This may results to clogging at the outlet point of the watershed during peak flows resulting to increase of water level during flooding [2]. This is what happened in Barangay Bangcod in the Manupali watershed.

Relief Features

Relief parameters mainly include elevation (Figure 2a), basin relief, and slope (Figure 2b)The topography of the watersheds reflects the general configuration of Bukidnon which is generally undulating, as expressed in terms of average percent slope. Manupali is higher on the average by 478 and 696 meters than Taganibong and Maramag, respectively. Relief ratio is obtained by dividing total basin relief and maximum basin length. Lower reliefratio values specifically 0.00041 to 0.00054 suggest a low relief and moderate to gentle slope[22]. The computed relief ratios of the watersheds (Table 1) suggest higher relief with steeper slope implying higher runoff rates.

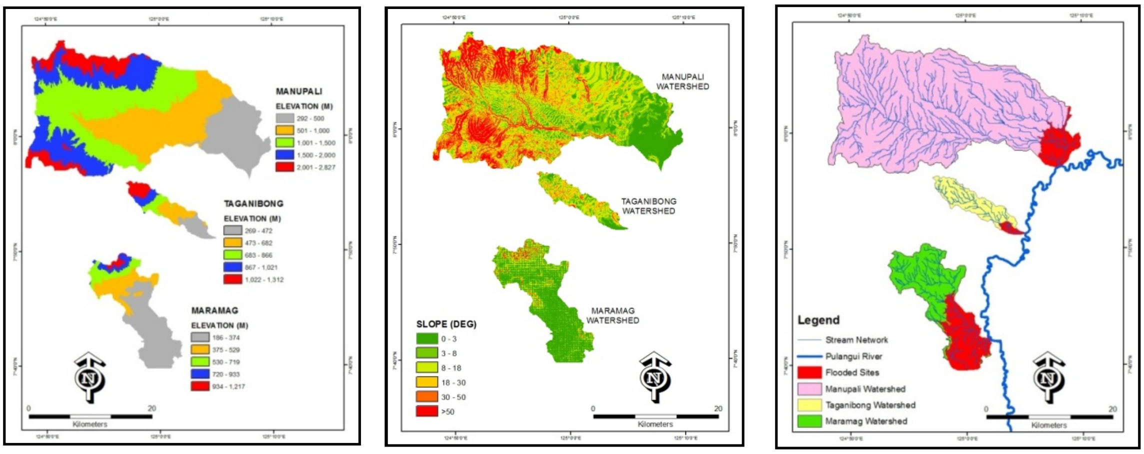
Stream Parameters

Thenumber and the total length of stream revealed to be directly proportional to the size of the watersheds (Table 1). These values were used to derive stream densities of the three watersheds. Watershed with a stream density value of 0.05 may have runoff which is not quickly removed from the landscape making it highly vulnerable to flooding and landslides[9]. Greater drainage density and stream frequency imply faster runoff and therefore the likelihood of flooding is high [22]. In general, high drainage density value is characteristic of watershed having permeable subsurface materials, sparse vegetation and mountainous relief as in the case of the three watersheds. Stream densities in the three watersheds were found to be 0.009 0.03, and 0.02 for Manupali, Taganibong and Maramag watershed, respectively. Higheststream order of 5 was observed inManupali and Maramag watersheds indicating more branching stream network as a characteristic of less elongated shape. High stream order

indicates strong structural disturbances and distorted drainage pattern [21].

Mapping of Flood-Prone Area

Geospatial analysis revealed that the specific barangays hit by flood included Bangcud, Dologon, and Base Camp within the Manupali, Taganibong and Maramag watersheds, respectively (Figure 2c). Flood regimes in these 3 barangays are clearly due to the morphologic characteristics of the respective watersheds, including rainfall intensity. The extent of flood-prone areasin the three barangays was observed to positively correspond to the slope in the floodplain zones of each watershed. High flood risk was expected to concentrate at the areas with flatter terrain. Base Camp (Maramag watershed) has the wider flooding extent due its largest area with flat ground surface at the low-lying zones.



a b c

Figure 2: a) elevation map; b) slope map; c) flood risk map

The above thematic maps spatially delineate local areas within the watershed that are vulnerable to flooding. These provide crucial data and information useful in other initiatives such as land use zoning and management that takes into account natural disasters such as flooding and landslides that will likely to occur under the light of climate change.

CONCLUSION AND RECOMMENDATIONS

The geomorphologic characteristics of the watersheds with emphasis to flood-prone zones were determined using the combine technology of GIS, GPS and DEM data. The likelihood of flooding with depth information at specific locations was delineated through GIS with data from GPS. The extent of

flooding at the low lying portions of the watershed was expected to correlate with the geomorphologic configuration of the sites such as area, land form, elevation and slope. Theapplication of GIS in natural disaster visualization and analysis seems limitless. However,it would be extremely beneficial to validate the results on the ground using local experiences and actual observations. The output of this study isuseful information for local government unitsin response to disaster risk monitoring and management provided results will be disseminated and utilized in actual disaster risk reduction and management initiatives.

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